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Abstract A manufacturer, in a fast moving consumer goods industry, buys Natural oils from a number of oil suppliers world-wide. The prices of these oils are the major raw material cost in producing the consumer goods, which are also sold world-wide. The volatility in the international prices of the Natural oils has significant impact on the planning and budgets decisions. Since the oils are bought and the finished products are sold in markets throughout the world, the manufacturer is exposed to a variety of market uncertainties and the resulting risks. These uncertainties are the raw material prices, the demand and the therefore the selling prices for the finished goods- all of which influence the profitability of the manufacturing firm. The risks can be minimised by entering into futures contract of appropriate duration, that is, by following a schedule of "forward"' purchase of oil (with specific series of future delivery dates) with the oil suppliers. We formulate this problem as a two-stage Stochastic Program (SP) using the futures and the spot prices for the Natural oil. This SP model gives robust decisions that hedge against the uncertainties in the Natural oil prices and the demand for the finished products. The uncertainty in the oil prices and the demand are modelled through a scenario generator. We have constructed a decision support system (DSS) that integrates the SP model, the scenario generator and the solution algorithm. This DSS also provides the decision maker a profile of the risk and return exposures for different policies.

Keywords: Natural oil cover policy, Stochastic program, hedged decisions, decision support systems.

Contents

1. Background

The decision problem

A manufacturer, in a fast moving consumer goods industry, buys Natural oils such as soft oils, palm oil, rape seed oil and coconut oil from a number of oil suppliers world-wide. The prices of these oils are the major raw material cost in producing the consumer goods such as margarine, soaps, detergents, which are also sold world-wide. Oils fall into 4 main types, depending on their physical properties and origin. These are: 1. Palm Oils derived from oil palm fruit; 2. Lauric Oils from coconut and oil palm nut kernels; 3. Soft Oils from soya beans, sunflower and rape seeds; 4. Tallow from animal waste processing.

Soya oil, soya beans and soya meal are traded on the Chicago Board of Trade (CBOT). Crude palm oil is traded on the Malaysian derivatives Exchange (MDEX) in Kuala Lumpur. There is some degree of substitution between the oils and their international price recognises this via their price differentials. All the prices move roughly together depending on the state of world prosperity and the balance between specific and overall supply and demand. The volatility in the international prices of the Natural oils has significant impact on the planning and budgets decisions. Since the oils are bought and the finished products are sold in markets throughout the world, the manufacturer is exposed to a variety of market uncertainties and the resulting risks. These uncertainties are the raw material prices, the demand and the therefore the selling prices for the finished goods- all of which influence the profitability of the manufacturing firm. The resulting risks can be minimised by entering into futures contract of appropriate duration, that is, by following a schedule of "forward" purchase of oil (with specific series of future delivery dates) with the oil suppliers.

Our aim is to develop a quantitative decision process that balances the risks of projected oil price fluctuations plus the carrying charge against the sales margin and the allowable frequency of sales price revision for each oil type and product. The target is to maximise margin at an acceptable risk for each product and sales market via setting the financial cover for the various oils.

Role of the derivatives products for hedging risks

A derivative can be defined as a financial instrument whose value depends on (or derives from) the values of other, more basic underlying variables. Very often the variables underlying derivatives are the prices of traded assets. The market for derivatives products have been outstandingly successful. There have been, however, few significant failures such as Barings [35], MGRM [9]. Lessons from these and similar crashes have been learnt. Adequate internal controls and margining system coupled with effective risk management have made trading in derivatives far more safer than equity cash markets.

One reason for derivative market to be successful is that it has been able to attract many different types of traders who want to hedge their exposure to risks. Such hedging is required to minimise the loss in the case of an unforeseen event in the future. Also the derivative market has a great deal of liquidity. When an investor wants to take one side of contract, there is usually no problem in finding someone that is prepared to take the other side. Three broad categories of traders can be identified: hedgers, speculators and arbitrageurs. Hedgers use options, futures and forwards to reduce the risk that they face from the potential uncertainties in the market variables; Speculators use them to bet on the future directions of a market variable; Arbitrageurs take offsetting positions in two or more instruments to lock in a profit.

An option provides its holder the right but not the obligation to buy/sell an asset at a future date. Since the option confers the right - a premium must be paid to exercise this right. A forward contract is an agreement between two parties whereby one contracts to buy a specified asset from the other for a specified price, known as the forward price, on a specified date in the future known as the delivery date or maturity date. This contract has similarities to an option contract if we think of the forward price as equivalent to the exercise price. However, what is lacking is the element of choice: the asset has to be delivered and paid for. A forward contract is also different from an option contract in that no money changes hands until delivery, whereas the premium for an option is paid up-front. It therefore costs nothing to enter into a forward contract. A further difference from option contracts is that the forward price is not set at one of a number of fixed values for all contracts on the same asset with the same expiry. Instead, it is determined at the outset, individually for each contract. A futures contract is in essence a forward contract, but with some technical modifications. Whereas a forward contract may be set up between any two parties, futures are usually traded on an exchange which specifies certain standard features of the contract such as delivery date and contract size. A further complication is the margin requirement, a system designed to protect both parties to a futures contract against default. Whereas the profit or loss from a forward contract is only realised at the expiry date, the value of a futures contract is evaluated every day, and the change in value is paid to one party by the other, so that the net profit or loss is paid across gradually over the lifetime of the contract.

Futures markets have long been considered a price insurance mechanism for risk-averse traders of commodities (Marshall [20]). The literature on futures markets and trading is dominated by this concept of hedging in the face of uncertainties. The futures market can be characterised by two broad categories: risk trading and strategic/competitive trading. The traditional hedging literature is by far the dominant theme in futures research and is based upon the idea that risk-averse traders of a commodity use the futures market to protect against adverse price movements. There a myriad or risk-response strategies, including use of inventories, production scheduling, forward contracting, and financial positioning to hedge financial positions (Dempster [6]). The introduction the futures market to this repertoire of instruments implies substitution between tools. While such substitution presumably would be most obvious at the time of introduction, changes in the relative costs and effectiveness of different risk-management tools would imply a continuing reallocation between futures trading and in one or more of these alternate measures. The strategic trading literature is relatively new, beginning with the work of Anderson and Sundaresan [1] and Newbery [24]. These researches breaks from the more traditional literature primarily in that it examines the case of a futures market for a commodity that is not traded in a perfectly competitive cash market. As a result of the imperfect underlying cash market, wherein at least one producer has some appreciable market power, a strategic role for futures markets appears that is absent in the more traditional literature. The notion that futures markets might provide a valuable service absent risk aversion or imperfect commodity markets was introduced by Working [33, 34] and advanced by the work of Telser and Higinbotham [27], Telser [26], and Williams [31, 32]. Working argued that futures provide a means of managing carrying charges for stored commodities (particularly grains) and could best be described as an arbitrage of the basis spread between spot and futures prices rather than as a hedge against absolute price movements. The latter papers join Working in shunning the risk aversion story. These papers employ a general transaction cost analysis to illustrate why firms might engage in futures trading.

The problem description

Supply side

Oils can be bought for dispatch on the day of purchase or at a specified date in the future. The price agreed for future dispatch depends on the market's view of future price fluctuations plus a carrying charge to finance any stock holding. This carrying charge would typically be 1% per month. The firm has to buy ahead to cover its physical requirements, that is to cover the time taken from dispatch from the oil supplier to delivery to its own trade customers. This is usually between 2 and 8 weeks, depending on the locations of the oil supplier and the trade customer. In addition to physical cover, the firm can hold financial cover by buying ahead to take advantage of anticipated oil price changes. To do this, the analyst in the firm monitors the key leading indicators for oil supplies and come to view of what is the most economically advantageous cover to hold for each of the various oils. Typical financial covers range from 1 or 2 weeks up to 36 week's supply. The cover policy is usually set following a detailed market analysis for a rolling 3 months ahead. Between the 3 monthly analyses, adjustments are made to allow for unexpected price developments.

Demand side

On the demand side the sales price agreed with the trade customers determines the margin over its raw material cost plus manufacturing costs for each consumer product. The period for which any price is fixed depends on the state of the retail market and the relative power of the firm and their trade customers. The period between selling price revisions ranges from weekly in high inflation countries to as high as a year in countries with low inflation and dominant supermarkets. The margin can be as low as a few percent to as high as 100% depending on the sophistication of the product. The sales demand is affected by selling price via the product's price/volume elasticity but is usually dominated by sales promotions and competitor activity. Marketing's role is to forecast sales demand, taking into account these factors and so set the amounts of oil needed for delivery in each period of the 12 months ahead. This forecast is typically revised on a rolling monthly basis.

The firm was using subjective techniques to set the cover policy and needed a quantitative decision process that balances the risks of projected oil price fluctuations plus the carrying charge against the sales margin and the allowable frequency of sales price revision for each oil type and product. The target is to maximize margin at an acceptable risk for each product and sales market via setting the financial cover for the various oils.

2. Stochastic programming modelling framework and Scenario representation

Stochastic program provides a mathematical framework that integrates the concept of a hedged decision with the decision makers attitude towards risks under uncertainty. As a consequence the optimum decisions for strategic plans and tactical operations are more flexible or robust in comparison with decisions obtained by applying deterministic models. SP models have been successfully applied to strategic planning problems for example: electric utility planning [2], goods distribution [5], capacity planning [11, 21, 30] communication network planning [12], transportation planning and vehicle routing [13, 18].

The uncertainties are represented as scenarios (future states-of-the-world). Kahn and Wiener[15] define a scenario as a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points. Scenarios reveal new strategic opportunities and threats, because they record explicit assumptions about the future and provide a common framework for discussion. To some extent, the wide acceptance of scenarios indicates that these objectives are indeed met: in their survey of the Fortune 1000 companies (Linneman and Lein [19]) found that approximately half of them reported to having used scenario based planning.

Current techniques for generating scenarios

Generation of scenarios require the domain experts to translate their knowledge of the causal dependencies into probability estimates; yet this mapping of knowledge may be problematic, especially if the experts are not accustomed to probabilistic thinking. Techniques to generate scenario trees for financial applications are vector auto-regressive processes [3], approaches based on principal component analysis[23], and stochastic simulation of economic variables and asset returns (Dempster and Thorlacius[7], Carino et al.[4] Mulvey[22]).

Hoyland and Wallace[14], Dupacova et al.[8] develop a scenario generation technique for multivariate scenario trees, based on optimization. This technique is also used for generating scenario trees for hydro inflow (Vitoriano et al.[29]), and dynamic portfolio insurance (Kouwenberg and Vorst[16]). In these applications different central moments are matched by solving a nonlinear optimization problem at each node of the scenario tree. In Hoyland and Wallace[14], a procedure to generate a scenario tree by solving a large nonlinear optimization problem was also suggested, but was not fully exploited. Kouwenberg and Vorst[16] compare random sampling, adjusted random sampling and optimization based (fitting the mean and covariances) approaches to generate the scenario tree.

3. Oil purchase model as a two-stage stochastic program

The relation between the spot and the future prices define market conditions. The market is in *backwardation* when the futures prices are below the spot price and in *contango* when futures prices are above the spot price. For commodities such as oil products which incur significant costs of physical storage over time normal market conditions lead to backwardation.

A strategic model

A cover policy is defined such that over fixed time interval in the future the company will have enough committed supply of Natural oils to meet the demand. For instance, through the analyses of the likely events in the future, the domain expert may recommend buying oil for 4 months ahead for the next year. Thus the firm will adopt this fixed period of 4 months for the cover policy. Our strategic model reflected this decision making technique of the end user. In this model there was no concept of hedging as nothing was bought from the spot market. The performance of the model was highly driven by the scenario set. Therefore, generating exhaustive and comprehensive scenarios was extremely important.

Indices

t=1 . . . T denotes the time periods,
c=0 . . . C denotes the possible cover periods to be considered,
$s = 1 \ldots S$ denotes the scenarios.

Data

p_s denotes the probability of scenario s,
f_{stc} future price of cover period c bought for delivery in time period t under scenario s,
d_{st} denotes the demand for time period t under scenario s,
π_{st} denotes the selling price (accounting for production cost) at time period t under scenario s.

Decisions

First-stage

δ_c takes the value 1 for the optimal cover policy and zero for the others.

Second-stage

x_{stc} denotes amount bought under cover period c for delivery in time t under scenario s,
E_c denotes expected cost of cover policy c.

Constraints

$$
\begin{aligned}
E_c &= \sum_{s=1}^{S}\sum_{t=1}^{T} p_s \pi_{st} x_{stc} - \sum_{s=1}^{S}\sum_{t=1}^{T} p_s f_{stc} x_{stc} \quad \forall\ c && (1)\\
d_{st} &= x_{stc} \quad \forall s,t,c && (2)\\
\sum_c \delta_c &= 1 && (3)\\
x_{st} \geq 0 & && (4)\\
E_c - (1-\delta_c)M &\leq Z \leq E_c + (1-\delta_c)M. && (5)
\end{aligned}
$$

Objective
Minimise Z
The group of constraints 1 determine the total expected cost for the cover policy. The second group of constraints 2 ensures demand is met for each time period and scenario for all possible cover policies. The cover period of 0 corresponds to purchased all the raw materials at the spot price. The thirds constraint 3 ensures that only one cover policy can be an optimal strategy. The final set of constraints is 5 are logical constraints linking Z to the optimal cover policy coupled with the previous constraint ensuring only one cover policy to be chosen, these ensure that the best cover policy is chosen.

A flexible operational model
We next constructed an operational model that allowed the decision-maker to buy from the spot market. This allows hedging of positions. Also this model can be expanded to incorporate both inventory and trading.

Indices
$t, t^{'} = 1 \dots T$ denotes the time periods,
$s = 1 \dots S$ denotes the scenarios,

Data
p_s denotes the probability of scenario s,
NB_{st} denotes the near-by (spot price) for scenario s at time t,
FP_t denotes the future price at time t
I_t denotes the future deliveries at time t
d_{st} denotes the demand scenario at time t
M denotes a large number.

Decisions
First-stage

x_t denotes amount bought on the futures market,

Second-stage

y_{st} denotes amount buy on the spot market,
Z denotes the objective function,
E_t denotes expected cost of cover policy t,
w_{st} denotes cost of cover policy taken for time t for scenario s,

Constraints

$$d_{st} = x_t + y_{st} + I_t \quad \forall\, t, s \tag{6}$$

$$
\begin{aligned}
w_{st} &= \sum_{t'=0}^{t} x_{t'} FP_{t'} + \sum_{t'=t+1}^{T} y_{st'} NB_{st'} \quad \forall \;\; t = 0, s \quad (7)\\
E_t &= \sum_{s=1}^{S} p_s w_{st} \quad \forall \; t \quad (8)\\
\sum_t \delta_t &\leq 1 \quad (9)
\end{aligned}
$$

$$x_{st} \geq 0, y_{st} \geq 0, \quad (10)$$

$$E_t - M(1-\delta_t) \quad Z \quad = M(1-\delta_t) + E_t \forall t. \quad (11)$$

Objective
Minimise Z
The group of constraints 6 specify that the demand is to be met either through buying in the spot market or the futures market. The group of constraints 7 determine the cost of buying in the futures and the spot market for each scenario and each cover policy t. The group of constraints 8 determine the total expected cost for the t^{th} cover policy. The constraint 9 specifies that only one cover policy can be selected. The constraints 10 are the non-negativity constraints. The group of constraints 11 determine the total cost of buying in the futures and the spot market.

A subjective method for generating scenarios
Scenarios for the future an the spot prices are generated using the rule based technique. Natural oils are agricultural products therefore are subject to Natural events such as storms, droughts, etc. which have a major effect on crop yield. Similarly, for soft oils, which originate from annual crops, the extent of cultivation is uncertain before the planting season is complete. The tree crops of palm and coconut, as well as tallow, are more predictable because the trees or animals take a few years to reach maturity and are not often destroyed before the end of their intended lives.

Overall then, the price of oils is certainly not predictable beyond the current growing season. Within any season, predictions can be made but only after any significant events have occurred. However, it is possible to extract trends from the past, which can be assumed to contain all of these perturbations but not in any future order.

The rules are subjective and have been recommended by the domain expert. We generate the scenario in two phases. In the first phase we assess the impact of the weather patterns, such as Monsoon failure and El Nino, on the harvest and therefore on the price of the Natural oil. In

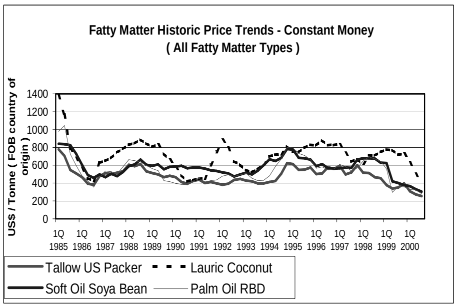

Figure 1. Historical price trend for the Natural oil.

the second phase we use the scenarios in the first phase to generate the scenarios for the selling price of the finished goods. In order to do this we use the historical data showing the impact of the current raw material cost on the selling price of the finished good. Our scenario generation technique does not follow Brownian motion but is adaptive as it uses the historical information. In order to enhance it further we believe that Artificial intelligence based techniques can be used.

4. Simulation and Risk analysis

SP provides a framework for a hedged strategy (decisions) whereas simulation provides a framework for evaluating such a strategy. By combining SP and simulation we are bring together the two frameworks which contribute towards the problem owners insight to the model.

Back testing

In order for the model to be used as a decision aid it is necessary to:

1 Collect and analyse the historical (transactional) data.

2 Obtain past reports from the domain expert in respect of various events which affected the spot and futures prices for the Natural oils and the selling price for the end products.

3 Run the model against historical data, verify that the decisions made through the model are indeed best hedged.

4 Quantify and analyse the different Risk metrics such as VAR, CVAR.

See Poojari et al.[25] for more specific details of the backtesting procedures. The historical data consisted of monthly supply price and demand data for 18 months. It was necessary to generate extreme scenarios such that we get hedged strategies. We performed backtesting at different level of risk by using randomly generated scenario trees.

Stress Testing

Quantitative researchers and theorist have been pushing to integrate stress test within the general risk management framework. In part this has taken the form of exploring mathematical techniques such as extreme value theory - a statistical approach to improve estimates of the 'tails' or extremes of distributions- to see whether rare events can be treated in a way that is more rigorous, and more tractable.

Stress tests is a mix of quantitative technique, expert judgement, imaginative flair and market intuition. This is particularly true in terms of specifying how fundamental risk factors interact with one another in a stressed market: known sensitivities and scenarios have to be layered into one another and made to behave in an economically plausible way, using expert judgement. Our experimentation with stress test Poojari et al. [25] reveals a linkage or contagion between risk factors that is profound but also non-obvious.

5. Prototype DSS tools

The implementation was tested by generating scenario trees from historical price data and the knowledge of the domain expert. We tested our optimal investment strategies (for specified levels of risk) using two frameworks: a DSS based Oil purchase analytics [25] and a Stochastic programming integrated environment[28].

Oil purchase analytics

We constructed a customised DSS for the firm. This DSS consisted of a the rule based scenario generator, the modelling environment (MPL [17]) and a solver (FortMP[10]). The problem is being used by the analyst to get a better insight into their decisions. The DSS is used to perform tactical decisions, say every 2 months, for every product-region combination the amount of financial stock (of Natural oil) that should be held. The input is the supply side forecast of the oil prices and the demand side forecast for a given product region. Figure 2 shows the screen-shots of base scenarios for the spot-prices in the DSS. Similarly we have base scenario for the demand and the future prices. These base scenario are used by the scenario generator to construct the future states of the world.

The DSS provides the user with the period of the cover policy, the profile of the cost for different cover policies (figure 3), the risk profile of the cover policies. For the given data set we have plotted the cost for implementing the zero cover (see figure 4), and the cost for implement-

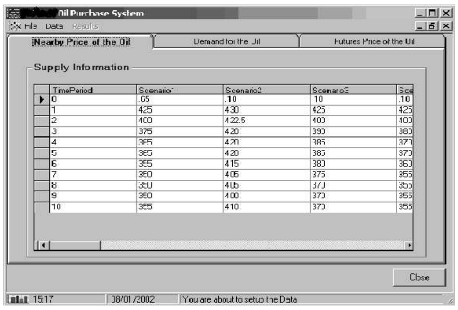

Figure 2. Base Scenarios for the spot prices.

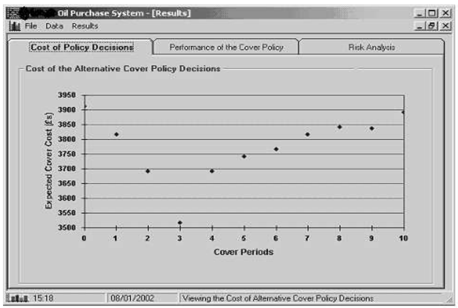

Figure 3. Profile of the cover policies.

ing the optimal cover policy (see figure 5).

The cover policy obtained on solving the model will be applied repeatedly over the time-horizon is 1 year. In our case we obtained a cover policy period of of 3 weeks ahead. Therefore, the firms would need to enter into a 3 weekly futures contract.

6. Discussions and Conclusions

In our investigation we have introduced operational research models to support decision making in a Corporate context and using financial market information and methods. We have presented Stochastic programming models to determine a period of the contract that the firm must enter into in the future's market for buying Natural oil. We have argued that SP provides a flexible modelling environment to represent the decision-maker's perception of the problem and the representation of uncertainty. We have presented a rule based scenario generator to generate the spot and the futures prices for the Natural oil, and the selling price for the end-products. We have developed two DSS tools to

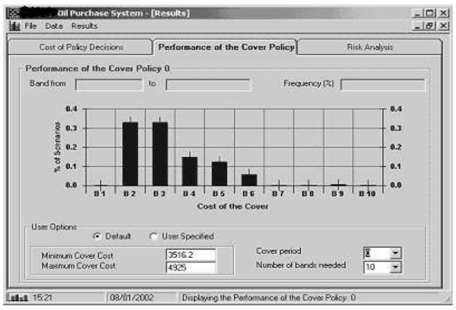

Figure 4. The cost distribution on buying from the spot price.

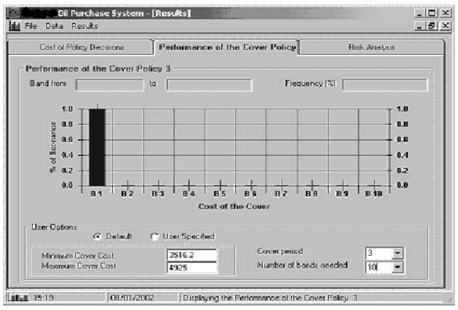

Figure 5. The cost distribution on buying ‘ best hedged’ cover.

model the underlying Stochastic programming problems. One was an Stochastic programming integrated environment and the other was an Oil purchase DSS. In order to test the quality and the robustness of the solutions for such stochastic models, we emphasised the need to perform simulation, back-testing and stress testing. We further provide a framework to compute the risk measures. This modelling framework can be applied to other fields such as corporate multinational’s forex exposure.

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